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US 4409601 A

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INT CL^{6} B41J 2/025 2/045 , H01L 41/04 41/09

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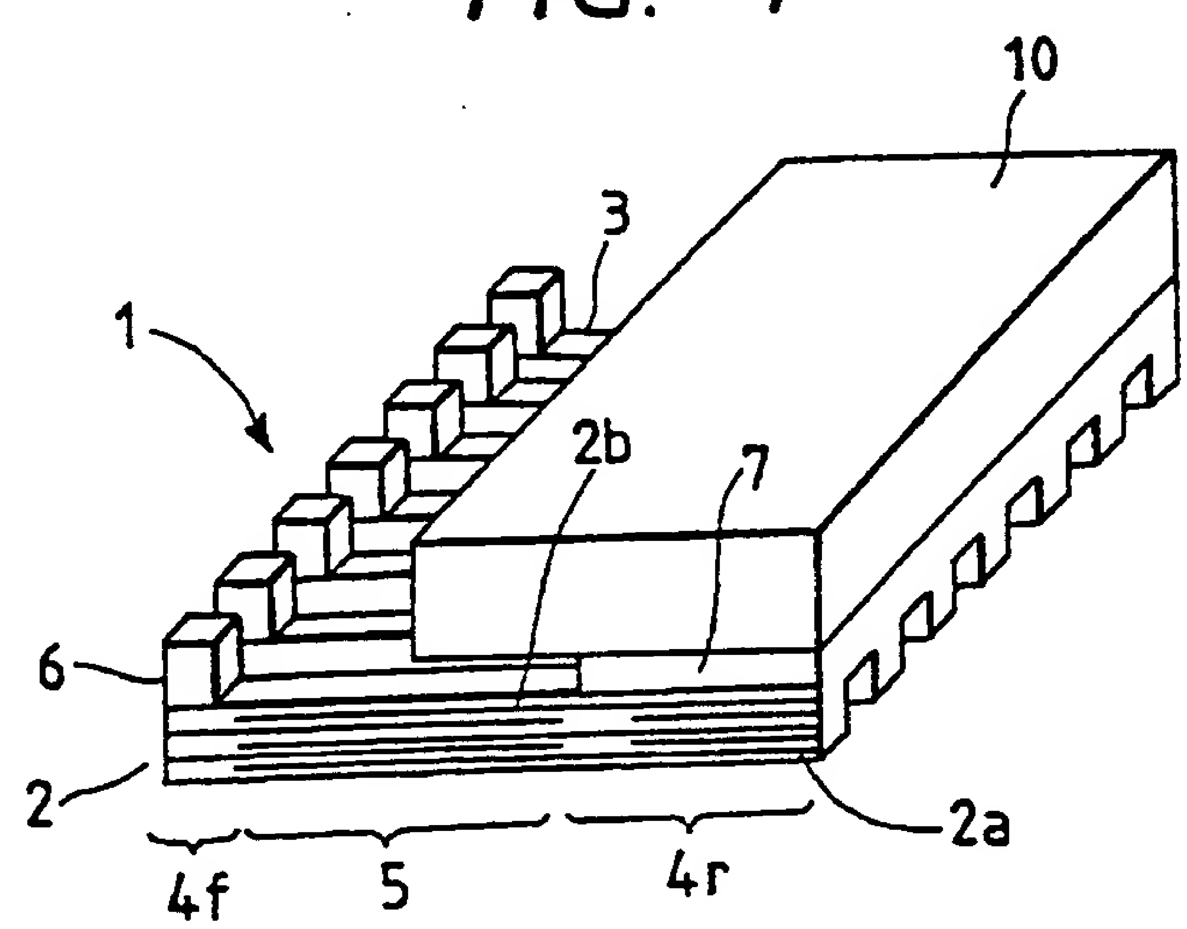
(54) Piezo-electric driver for an ink jet recording head

(57) Conductive layers 2b are laminated as an active region 5 in a piezo-electric plate 2 except the front and rear end portions 4f, 4r thereof to provide front and rear inactive portions, a pressure facilitating front end plated 6 and a vibrator coupling rear end plate 7 are fixedly mounted on the front and rear inactive portions, respectively, and the front end portion of the piezo-electric plate together with the front end plate are cut at predetermined intervals into pieces, namely, piezo-electric units. The front ends of the units are secured to portions (49, Fig. 2) of the wall (47) of an ink chamber (45) to depress the wall portions in response to unit energisation. Front end plates 6 may be provided at both sides of the plate 2 (Figs. 8 and 9). Details of the construction of the plate 2 and the cutting of plurality of plates from a piezo-electric sheet are given in the specification.

FIG. 1



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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

FIG. 3(a-1)

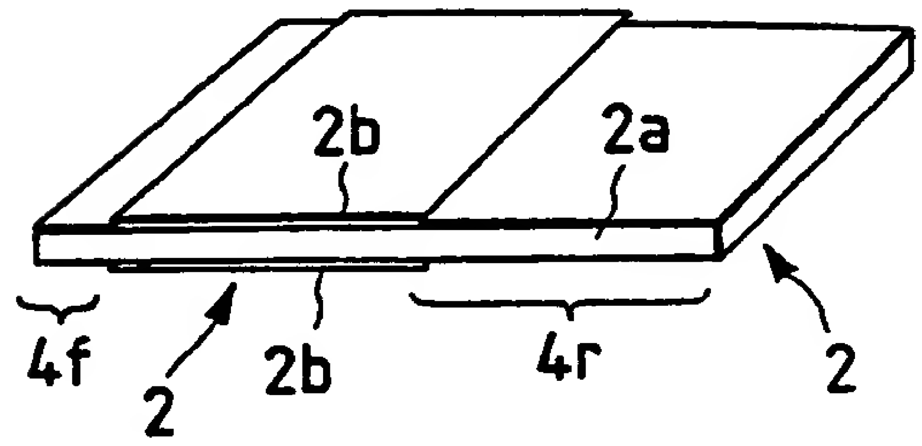


FIG. 3(a-2)

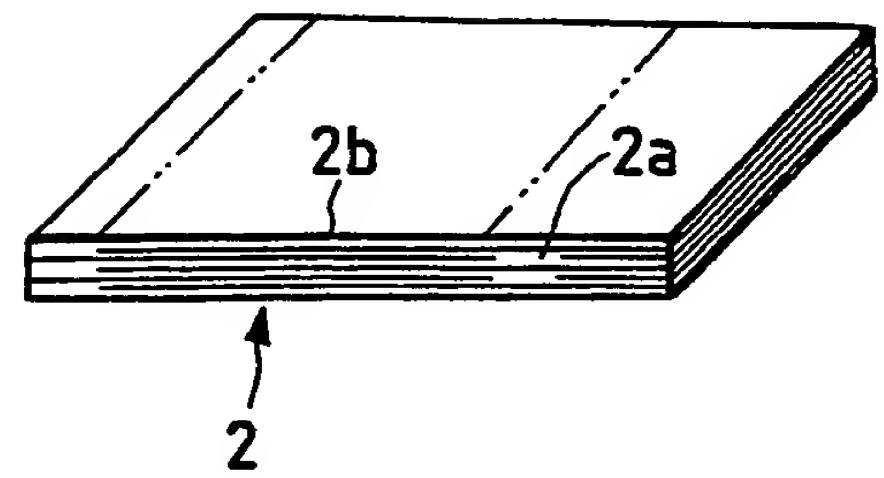


FIG. 3(b)

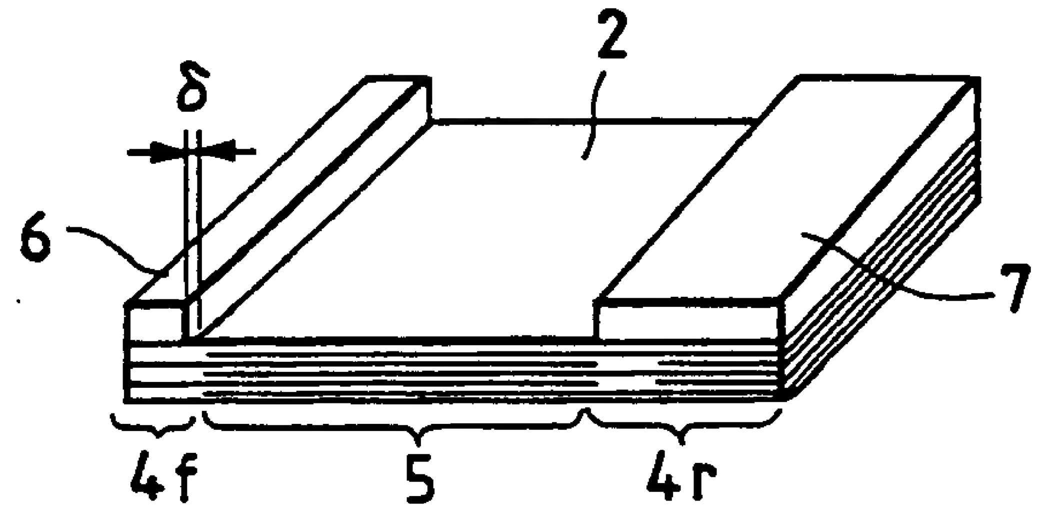


FIG. 3(c)

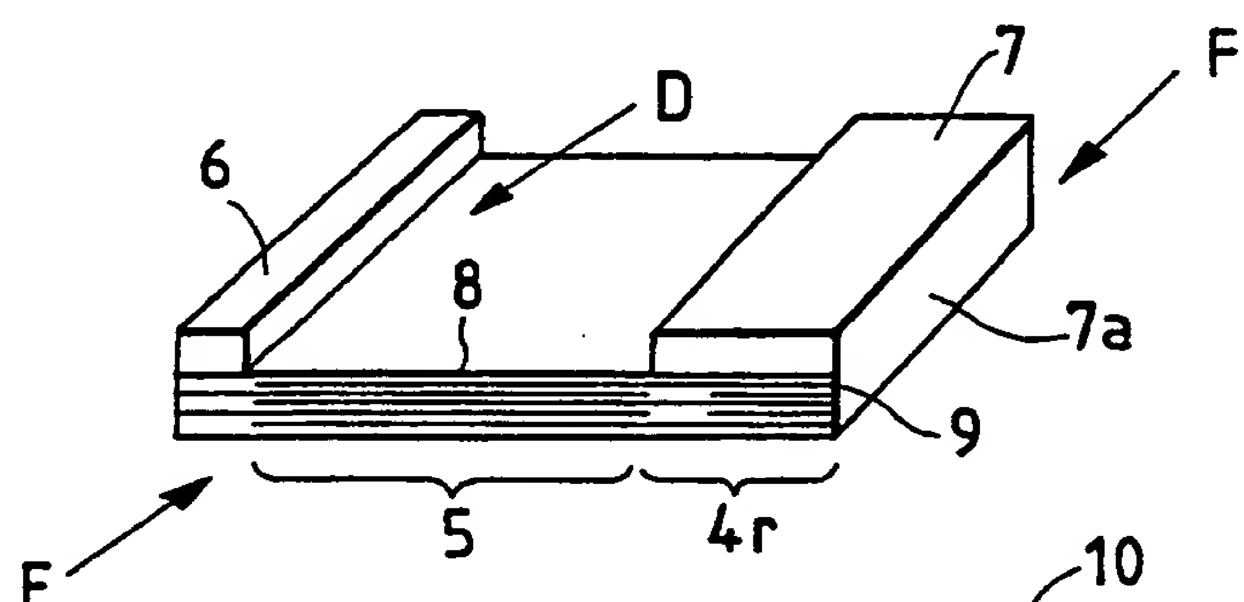


FIG. 3(d)

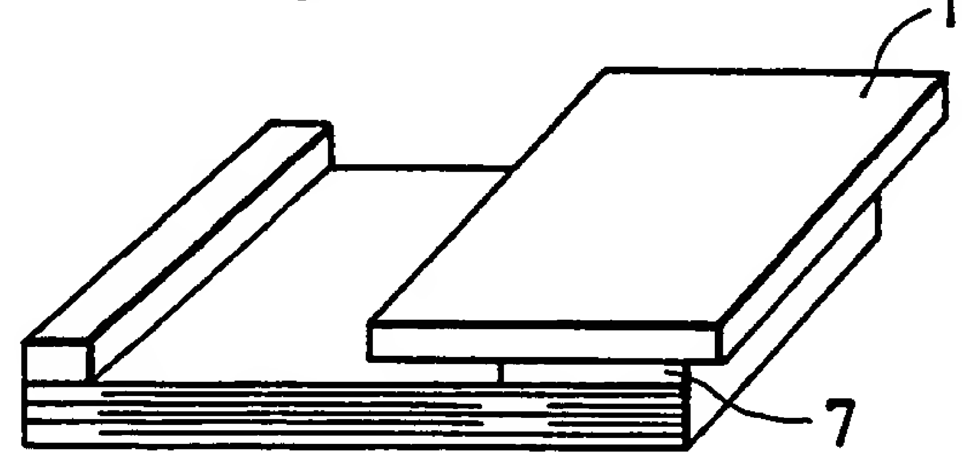


FIG. 3(e)

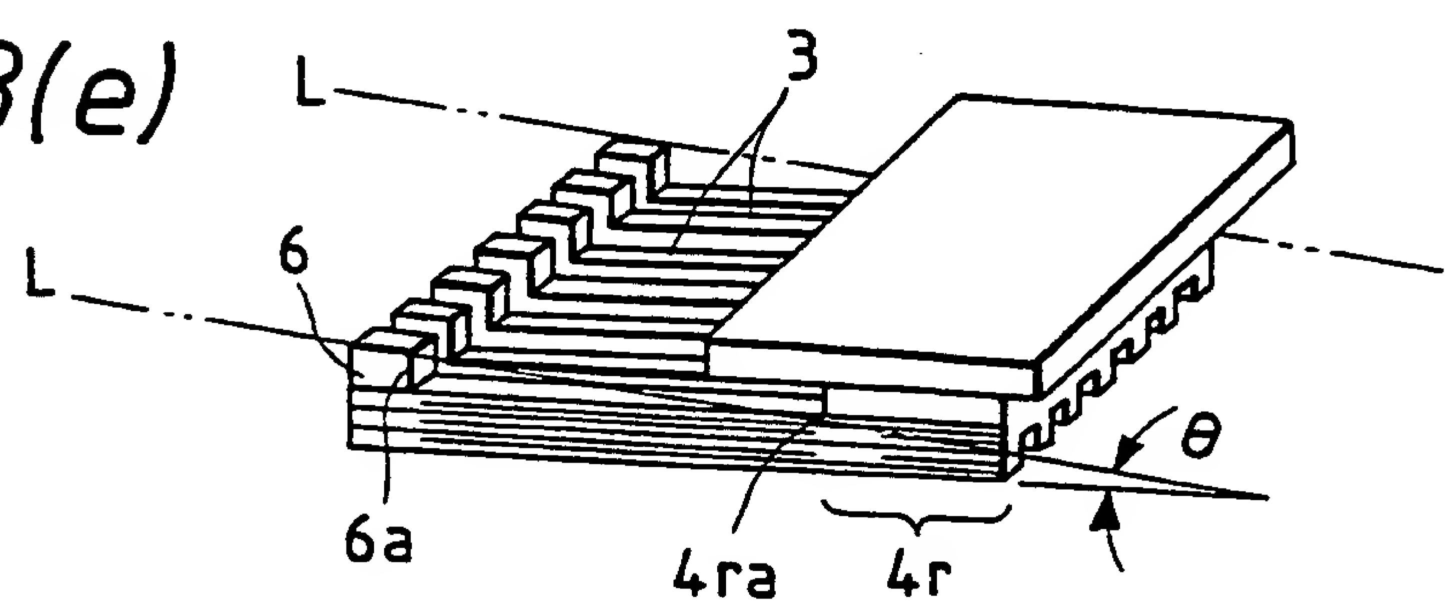


FIG. 5(a)

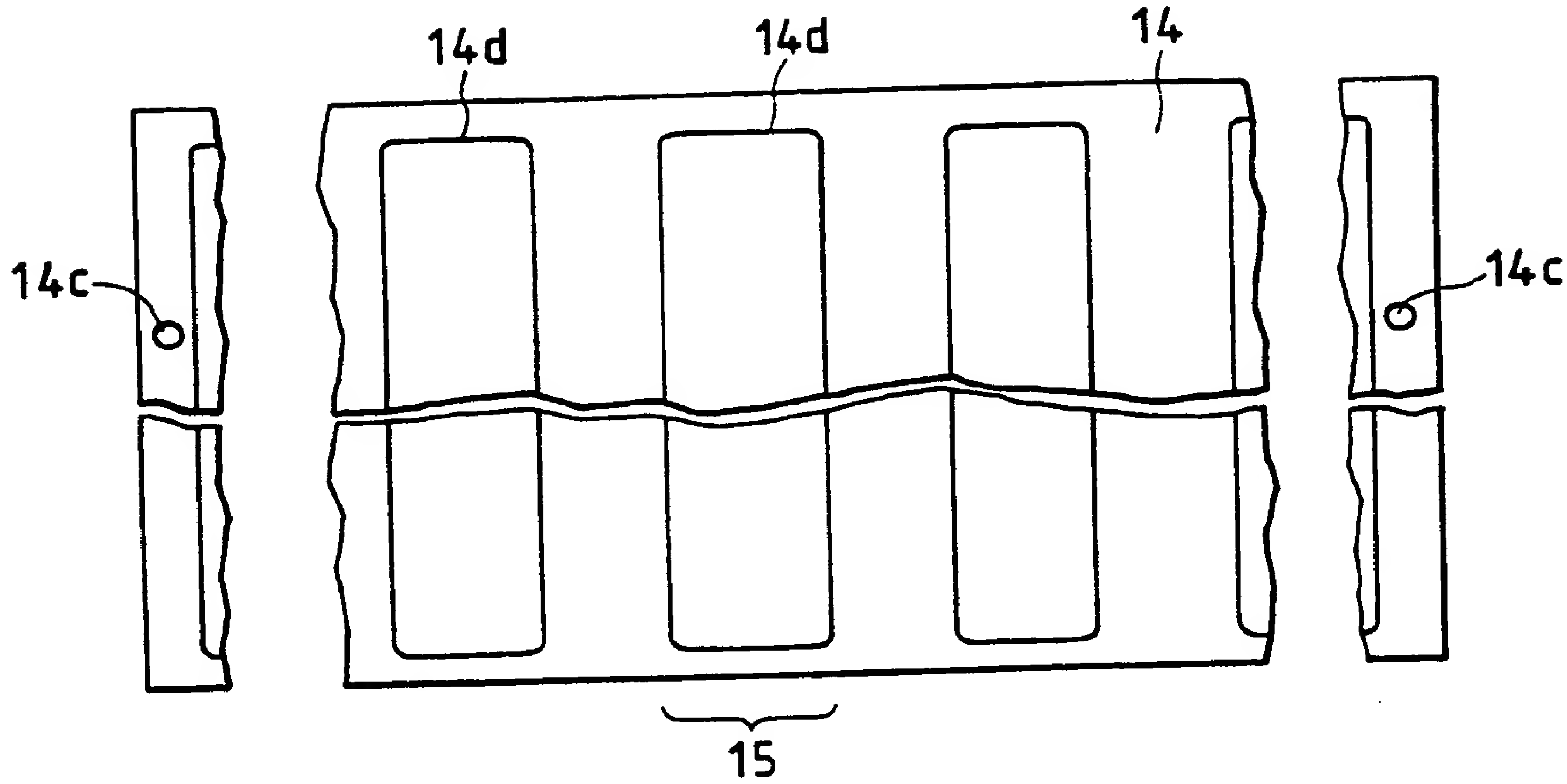


FIG. 5(b)

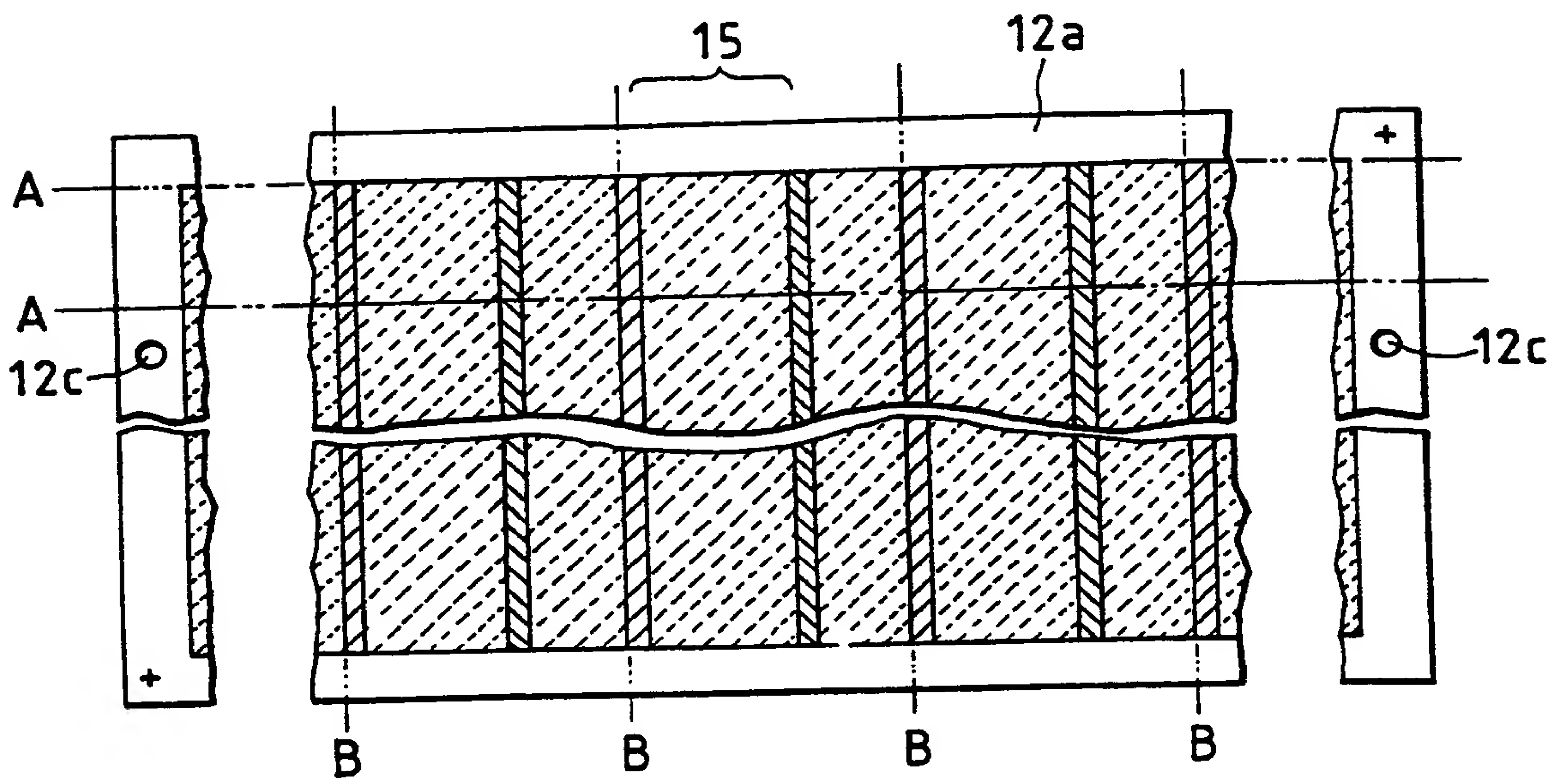


FIG. 5(c)

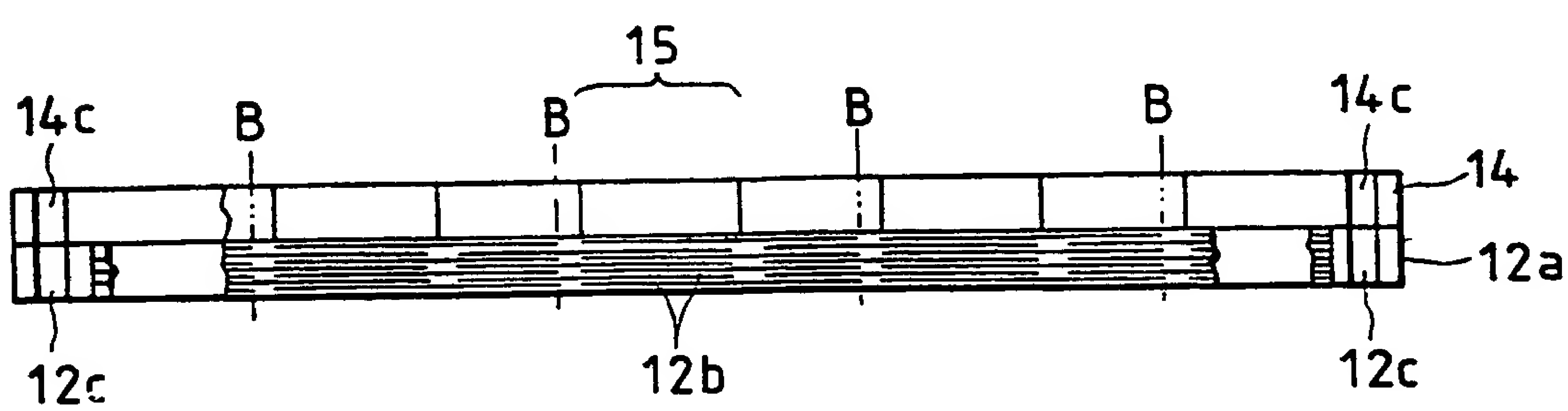


FIG. 8

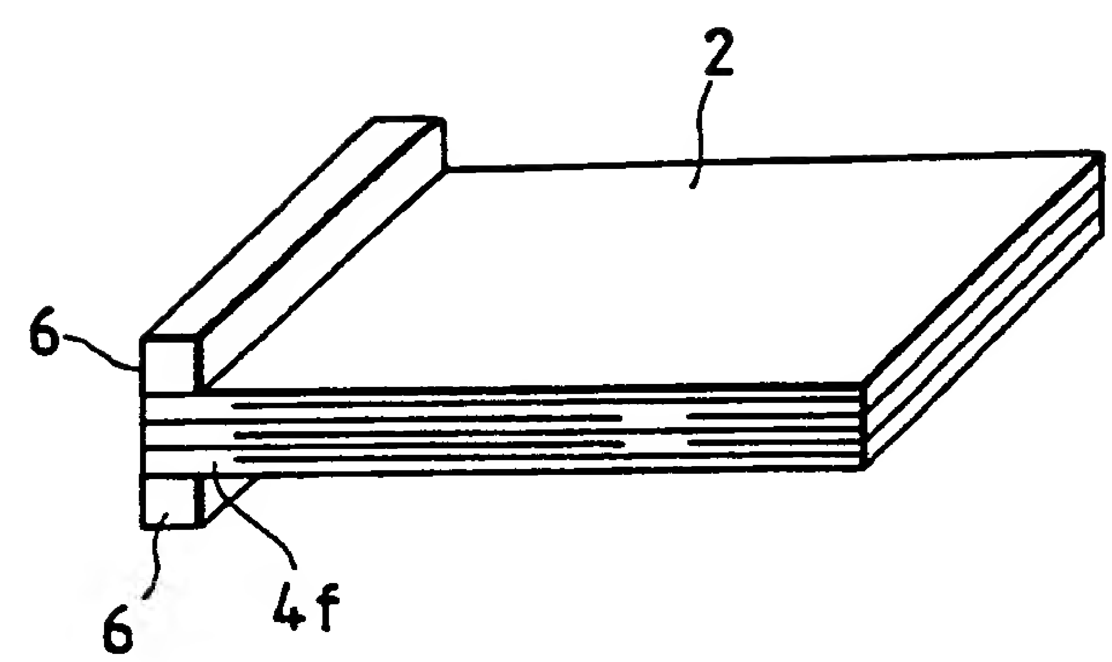


FIG. 9

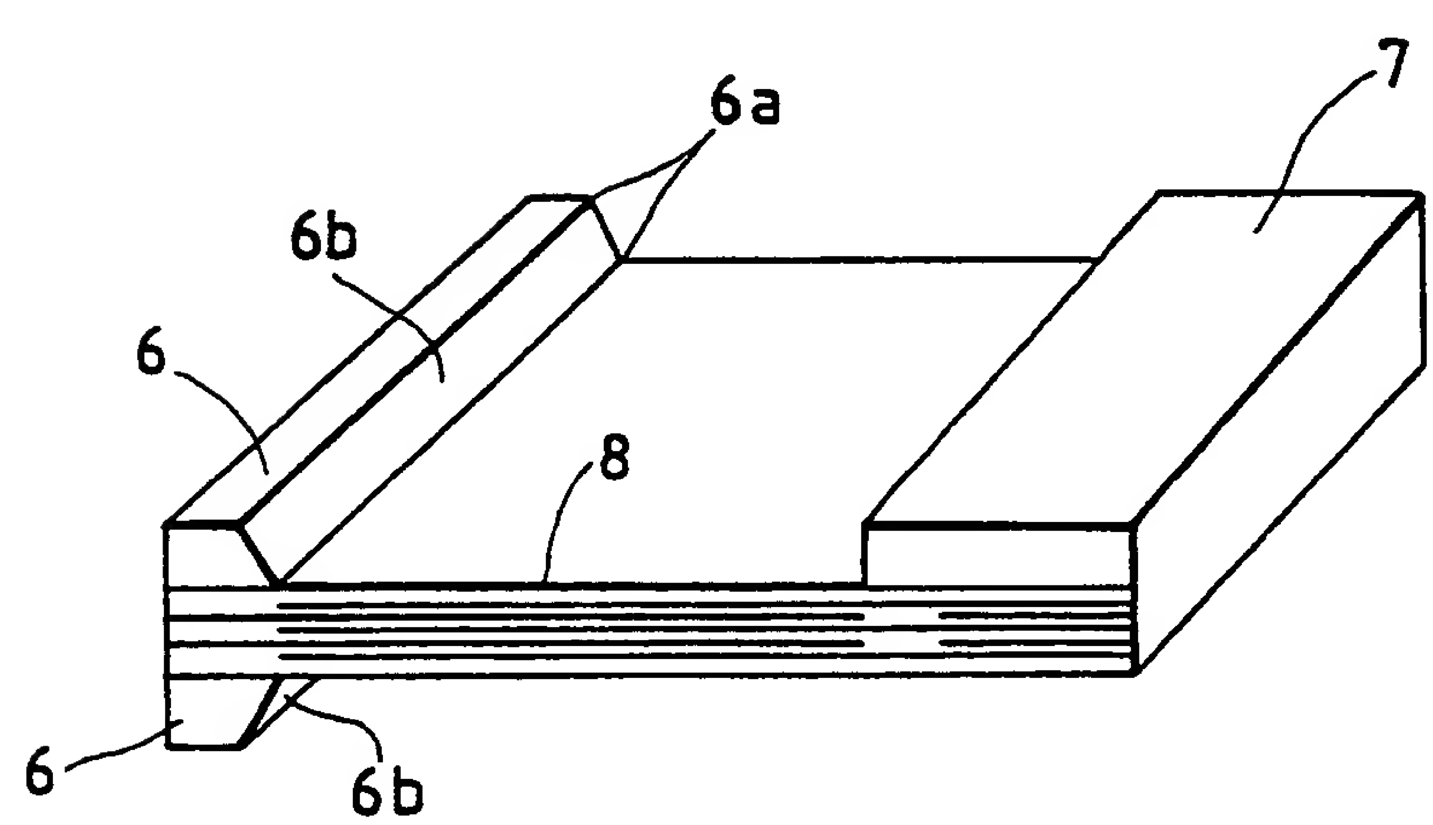
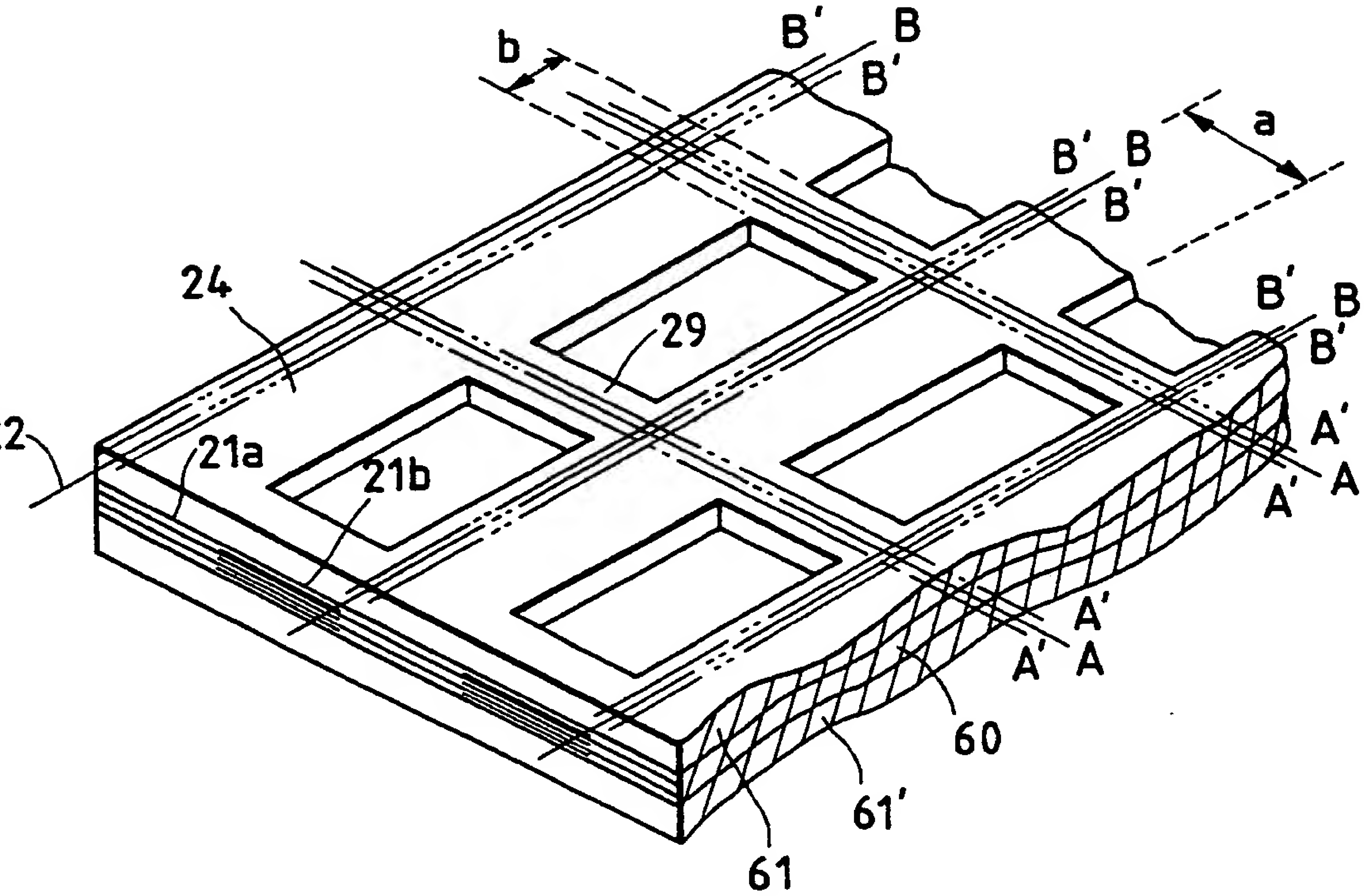


FIG. 11


b
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60
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61

FIG. 12

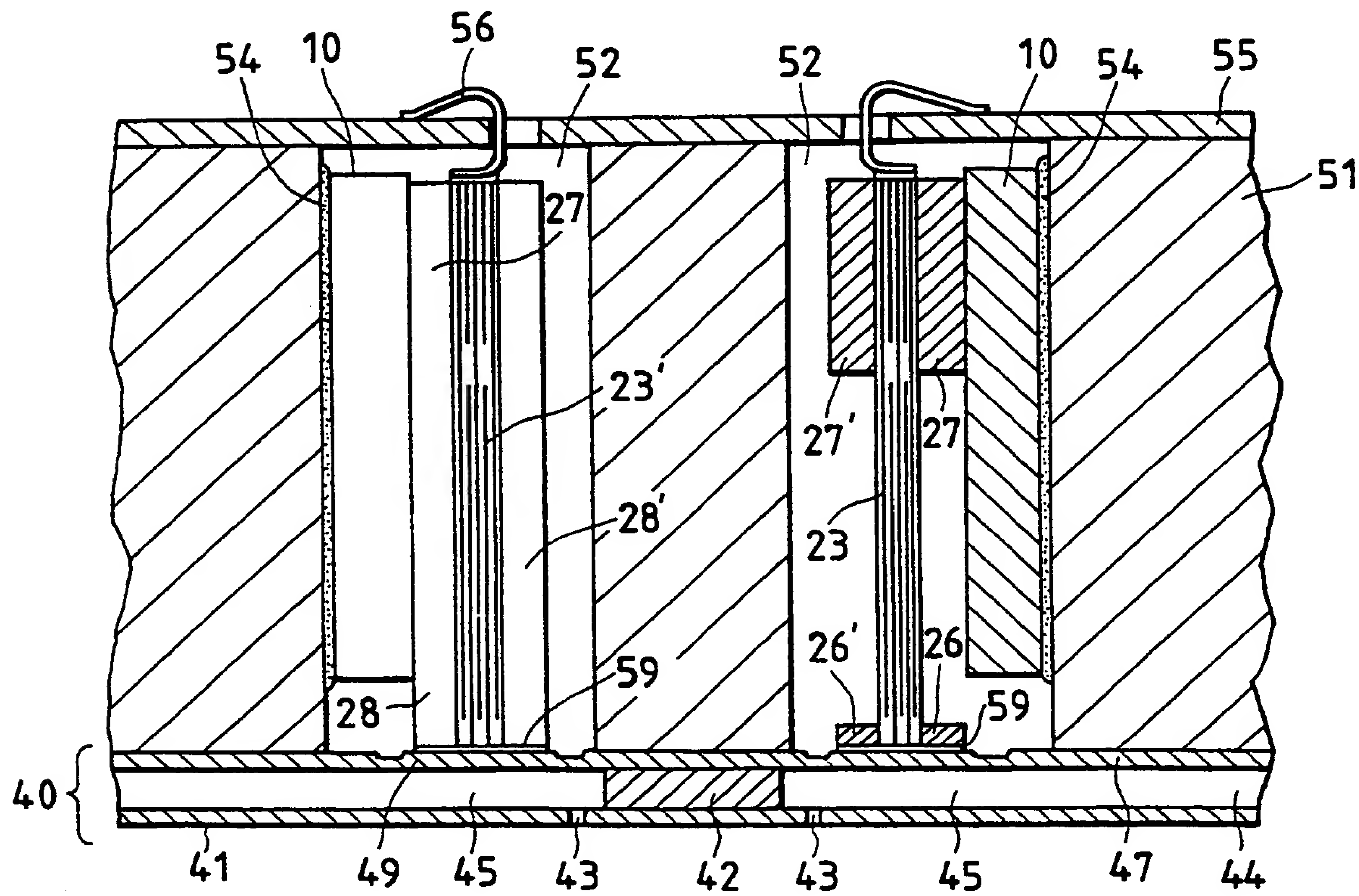
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FIG. 15a

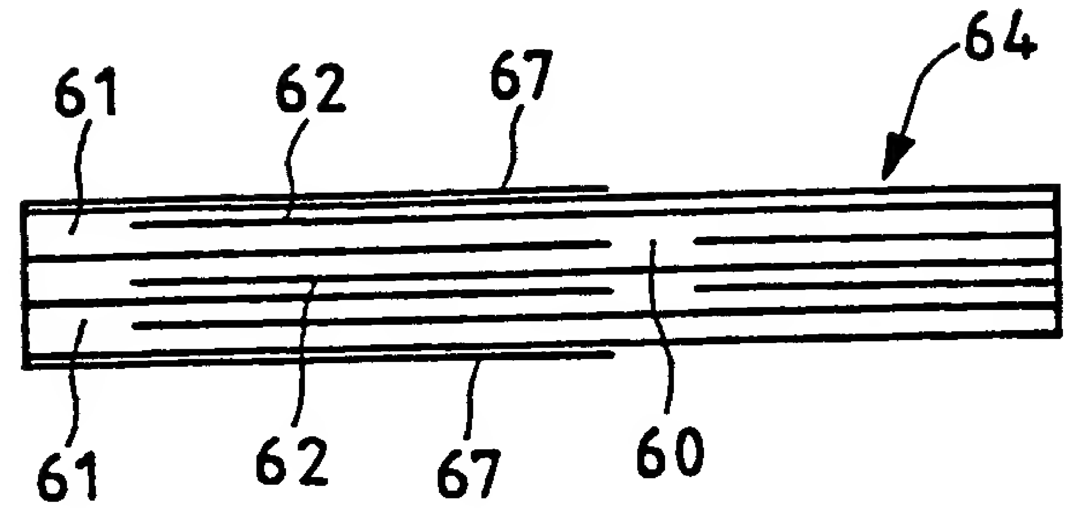


FIG. 15b

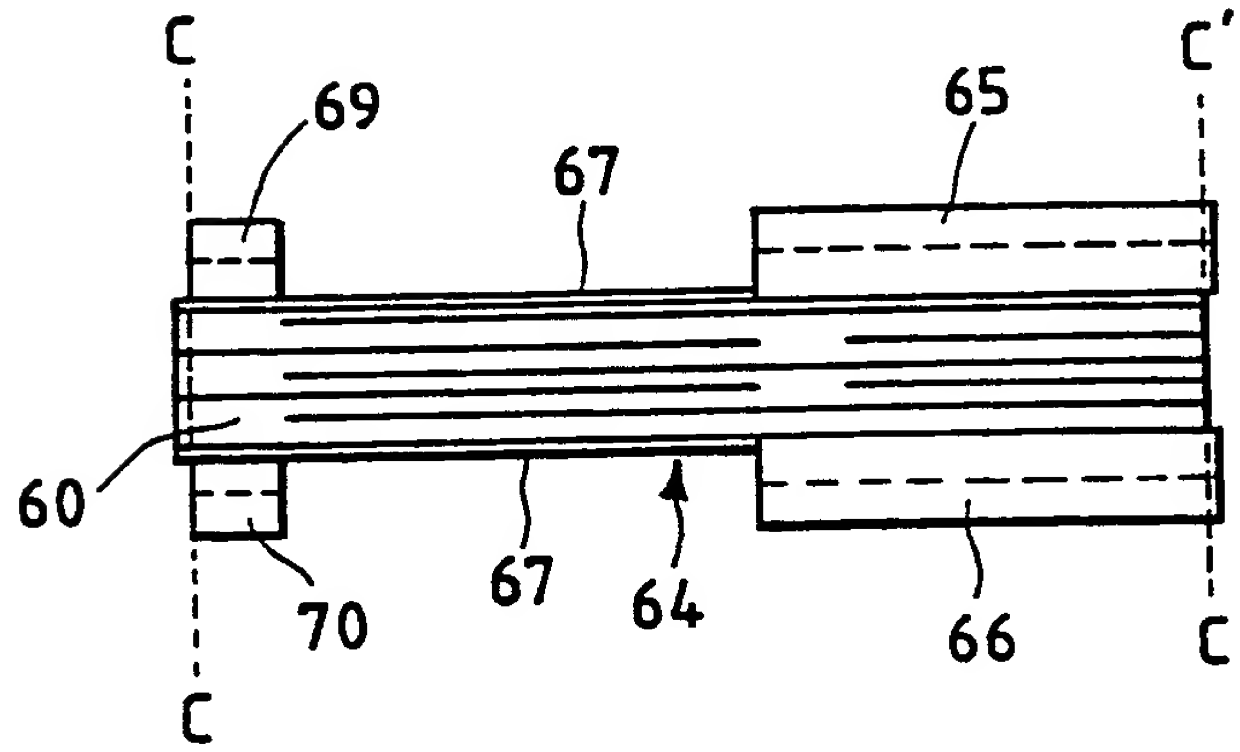


FIG. 15c

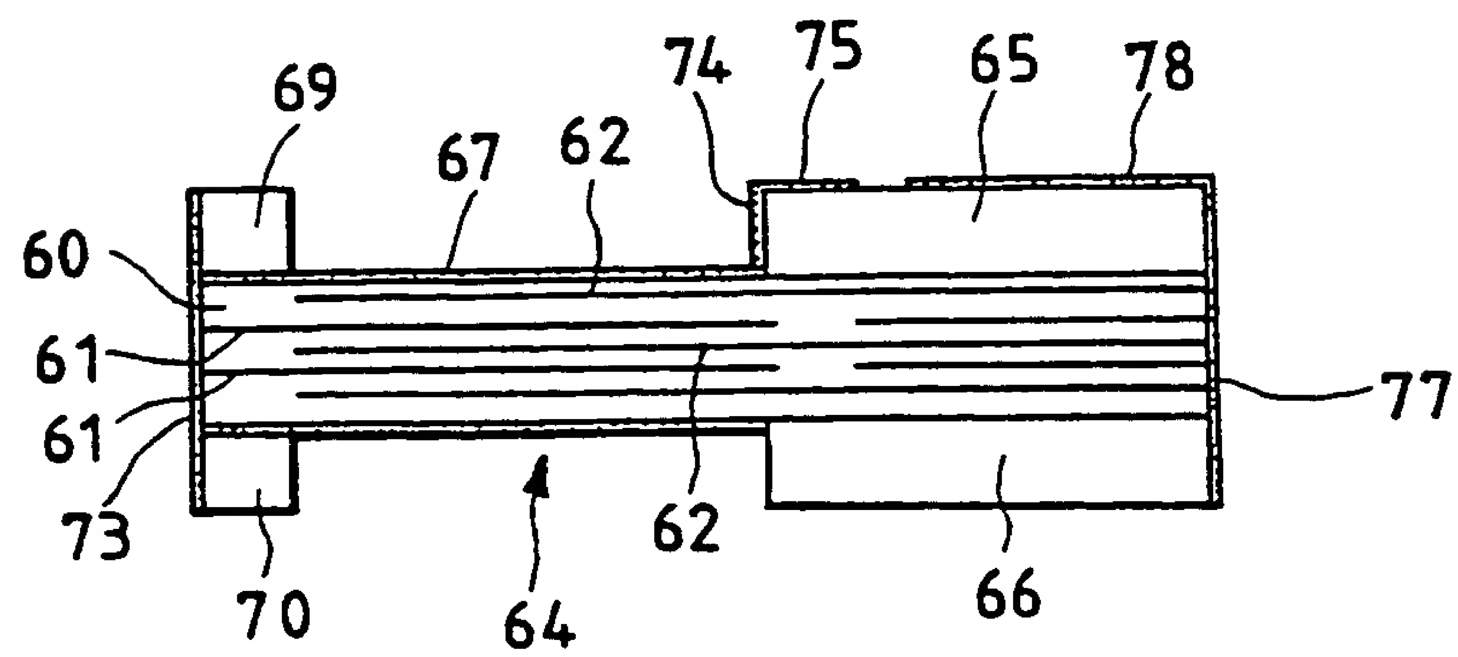
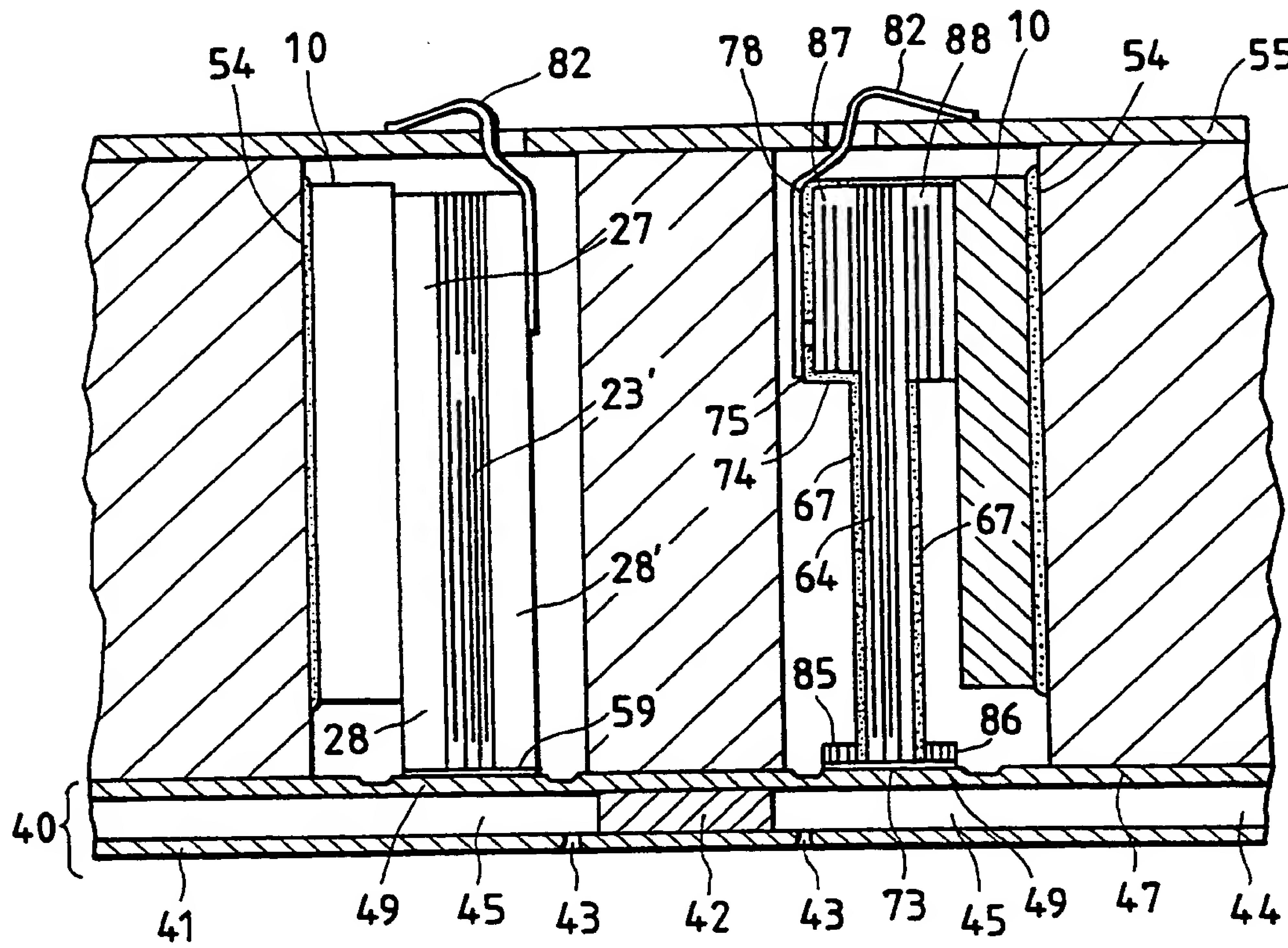


FIG. 17



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is necessary to elongate each of the pressure chambers in the ink jetting direction to allow the latter to have an internal volume large enough to contain jet ink droplets. In addition, it is necessary to form annular grooves in the portions of the vibrating boards which confront with the peripheries of the pressure chambers, so that the portions thus thinned receive the small displacement of the piezo-electric vibrators with high efficiency.

The recording head may be modified to meet the above-described requirements; however, the effects of such a modification is limited. That is, if the island portion defined by the annular groove is longer than a certain value, then only the portion thereof which is in abutment with the piezo-electric vibrator is bent and the pressure that can be applied to the ink in the pressure chamber is limited.

In view of the foregoing, an object of the invention is to provide a novel piezo-electric driver for an ink jet recording head which has piezo-electric vibrators limited in displacement to pressurize the ink in the pressure chambers with high efficiency, and a method of readily manufacturing the piezo-electric driver with high accuracy.

The foregoing object of the invention may be achieved by the provision of:

(1) a piezo-electric driver for an ink jet recording head comprising,

a piezo-electric plate having at least a front end portion as an inactive region, and another portion in which conductive layers are laminated, the piezo-electric plate is cut at predetermined intervals

Fig. 1 is a perspective view showing a piezo-electric vibrator assembly, which constitutes one embodiment of this invention.

Fig. 2 is a sectional view showing an example of an ink jet recording head using the piezo-electric vibrator assembly shown in Fig. 1.

Fig. 3 shows perspective views for a description of a method of manufacturing the assembly shown in Fig. 1.

Fig. 4 is a perspective view showing the arrangement of a device for forming piezo-electric vibrators.

Fig. 5 shows another embodiment of the invention. More specifically, FIG. 5(a) is a diagram showing a front and rear end plate forming layer; FIG. 5(b) is a diagram showing a piezo-electric plate forming layer; FIG. 5(c), is a diagram showing the laminate of those layers.

Fig. 6 is a perspective view showing a piezo-electric plate in another embodiment of the invention.

Fig. 7 is a perspective view for a description of a method of manufacturing the piezo-electric plate shown in Fig. 6.

Fig. 8 is a perspective view showing another embodiment of the invention.

Fig. 9 is a perspective view showing a piezo-electric vibrator assembly, which constitutes another embodiment of the invention.

Fig. 10 shows a piezo-electric vibrator assembly, which constitutes another embodiment of the invention. More specifically, parts (a) and (b) of Fig. 10 are perspective views showing the top and the bottom of the piezo-electric vibrator assembly, respectively;

10 fixedly secured to the rear end portion of the piezo-electric plate 2 through a rear end plate 7 adapted to combine piezo-electric elements together, thus coupling the piezo-electric plate 2 to an ink jet recording head.

More specifically, in the assembly 1, one of its components, namely, the piezo-electric plate 2 is formed as follows: First, a paste-like piezo-electric material layer 2a having a front end portion and a rear end portion and a middle portion between them as viewed in the longitudinal direction is obtained. Conductive layers 2b are laminated in the middle portion of the paste-like piezo-electric material layer 2a so that the middle portion serves as an active portion 5. The remaining portions; i.e., the front end portion and the rear end portion serve as a front end inactive portion 4f and a rear end inactive portion 4r, respectively. The front end plate 6 and the rear end plate 7 are formed by using a paste-like free-cutting ceramic material which is, for instance, the same as the piezo-electric material. The front and rear end plates 6 and 7 thus formed are mounted on the front end inactive portion 4f and the rear end inactive portion 4r, respectively. These components are then formed into one unit by sintering.

In the embodiment, as shown in Fig. 3(e), the front end portion of the piezo-electric plate 2 together with the front end plate 6 is cut into pieces like the teeth of a comb with a wire saw or dicing saw, until the cutting line reaches the straight line connecting the rear edge of the top 6a of the front end plate 6 and the front edge 4ra of the rear end inactive portion 4r. The pieces thus obtained are piezo-electric driving elements 3 which, in response to voltage applied thereto, are moved across the

Further in Fig. 2, reference numeral 51 designates a holding block of plastic which is fixedly secured to the rear surface of the flow-path forming member 40, to position the piezo-electric vibrator assemblies 1. The holding block 51 has two piezo-electric vibrator unit mounting holes 52 which have a width corresponding to the longitudinal length of the pressure chambers 45 and are arranged along the lines of the nozzles 43. The holding block 51 is mounted on the vibrating board 47 with an adhesive agent by utilizing a reference hole formed in the flow-path forming member 40.

A pair of piezo-electric vibrator assemblies 1 are inserted into the mounting holes 52 in such a manner that they face each other. As shown in Fig. 3(d), the metal plate 10 is larger than the rear end plate 7; that is, the former 10 is protruded from the upper and lower ends and the right and left ends of the latter 7. The metal plates 10 are bonded to the surfaces of the mounting holes 52 with an adhesive agent 54. In this operation, each of the metal plates 10 is positioned by using guide grooves formed on both sides of the mounting hole 52 so that the piezo-electric vibrators 3 are set on the portion 49 of the vibrating board 47 with high accuracy and the piezo-electric vibrators 3 are also prevented from being inclined relative to the board 47 (i.e. in the direction of thickness). That is, positioning the metal plate 10 in the above-described manner allows the piezo-electric vibrators 3 to be bonded to the rear surfaces of the island portions 49 of the vibrating board 47 with adhesive agents 59. The adhesive agents 59 are applied to the end faces of the piezo-electric vibrators 3 with the end faces of the piezo-electric vibrators 3 in plane contact with the island portions 49. Fig. 2 also

middle active portion has been formed (see Fig. 3(a-1)).

A multi-layer type piezo-electric plate is formed as shown Fig. 3(a-2). A paste-like piezo-electric material layer 2a is formed to a thickness of 15 to 30 μm, and conductive layers 2b are alternately formed to a thickness of about 3 μm in such a manner that internal electrodes extended from the front and rear ends are overlapped in the middle portion of the piezo-electric material layer 2a leaving margins at the front and rear end portions. This process is repeated several times to obtain a green sheet for a multi-layer type piezo-electric plate 2 having the front and rear inactive portions 4f and 4r.

The remaining manufacturing steps will be described with reference to the multi-layer type piezo-electric plate 2. The green sheet thus formed for the piezo-electric plate 2 is processed as shown in Fig. 3(b). That is, the front and rear end plates 6 and 7 are mounted on the front and rear inactive portions 4f and 4r, respectively.

More specifically, the front end plate 6 of free-cutting ceramic material which is substantially equal in thickness to the piezo-electric plate 2 is mounted on the front end inactive portion 4f with a small gap δ, preferably 0.0 to 0.5 mm, between the front end plate 6 and the active portion 5. Similarly, the rear end plate 7, which is larger in width than the front end plate 6, is mounted on the rear end inactive portion 4r. Thereafter, the piezo-electric plate 2 and the front end plate 6 are cut so that their front end faces are flush with each other, and then the piezo-electric plate 2 and the front and rear end plates 6 and 7 are combined into one unit by sintering. Alternatively, plates 2,6 and 7 may be

Finally, the piezo-electric vibrator assembly 1 thus formed is processed as follows: The assembly 1 is fixedly held with a jib or jig. Then, as shown in Fig. 3(e), the front end portion of the assembly 1 is cut at intervals corresponding to the pitch of arrangement of the nozzles 43 into pieces like the teeth of a comb until the cutting line reaches the straight line L connecting the rear edge 6a of the top of the front end plate 6 and the front edge 4ra of the rear end inactive portion 4r. The cutting is performed at an angle θ to the plane of the piezo-electric plate 2.

Fig. 4 shows an example of a device for cutting the piezo-electric vibrator assembly 1. Sloped mounting members 34 are mounted on a jig body 32 which is moved vertically while being held in parallel with a wire saw 31. More specifically, each sloped mounting member 34 has a workpiece mounting surface 33 which is sloped in correspondence to the angle of inclination of the aforementioned straight line L, and it is fixedly mounted on the jig body 32 with the workpiece mounting surface 33 set oblique with the wire saw 31. The metal plate 10 is fixedly secured to the workpiece mounting surface 33 in such a manner that the front end portion of the piezo-electric plate 2 extends upwardly. Under this condition, the jig body 32 is moved vertically towards the wire saw 31, to cut the piezo-electric vibrator assembly in the above-described manner.

Fig. 5 shows another embodiment of the invention, in which a number of piezo-electric plates 2 can be formed from a large size plate. Fig 5(a) shows a front and rear end plate forming layer. Fig 5(b) shows a piezo-electric plate forming layer 12a and Fig. 5(c) shows the lamination of those layers.

First, a piezo-electric plate forming layer 12a is formed by using a paste-like piezo-electric material which is large enough to arrange a number of piezo-electric

on the surface thereof.

As was described above, the internal electrodes 12b do not extend outside the piezo-electric plate forming layer 12a. Hence, the formation of the external electrodes can be achieved without a mask which covers the outer side of the piezo-electric plate. After the formation of the external electrodes, a voltage of 75v is applied to those electrodes for one minute for polarization. Thereafter, the resulting product is cut along cutting lines A to obtain a number of piezo-electric plates 2.

As shown in Fig. 2, in the piezo-electric vibrator assembly 1 formed in the above-described manner, the piezo-electric vibrators 3 are combined together with the rear end plate 7 as a common base, and the front end plate 6 is cut in correspondence to the piezo-electric vibrators 3, thus uniformly depressing the island portions 49 on the vibrating board 47.

Figs. 6 and 7 shows another example of the piezo-electric vibrator assembly according to the invention, and its manufacturing method.

In the piezo-electric vibrator assembly 1, a piezo-electric plate 22 has dummy vibrators 23' on both sides. The dummy vibrators 23' are used only to position other components during assembling; that is, they are not related to the recording operation of the recording head at all. A front end plate 26 and a rear end plate 27 are coupled to each other through side plates 28 mounted on the dummy vibrators 23' of the piezo-electric plate 22, so that the latter 22 is held reinforced during both forming and installing the piezo-electric vibrator assembly 1.

The assembly is manufactured as shown in Fig. 7. A piezo-electric plate forming green sheet 60

of a comb to form a number of piezo-electric vibrators 23.

In the above-described method, the front end plate 6 (or 26) and the rear end plate 7 (or 27) are mounted on the piezo-electric plate 2 (or 22) and are sintered into one unit (see Fig. 3(b)). However, the same effect can be obtained by processing those components as follows. The piezo-electric plate 2 (or 22), the front end plate 6 (or 26), and the rear end plate 7 (or 27) are sintered separately, and then they are combined into one unit by using a suitable adhesive.

In addition, as shown in Fig. 8 a pair of front end plates 6 may be fixedly mounted on the upper and lower surfaces of the front end inactive portion 4f of the piezo-electric plate 2. In this case, the island portions 49 of the vibrating board 47 can be more widely pressed with high stability.

Fig. 10 shows another embodiment of the invention. More specifically, Fig. 10(a) and (b) are a perspective top view and a perspective bottom view showing the top and bottom of another example of a piezo-electric vibrator assembly, respectively, and Fig. 10(c) is a front side view of the assembly. In Fig. 10, reference numeral 23 designates the above-described piezo-electric vibrators; and 23', the above-described dummy vibrators. The dummy vibrators 23' are provided on both sides of a group of piezo-electric vibrators 23 and they are used only for positioning other components during assembling; that is, they are not related to the recording operation of the recording head at all. The above-described rear end plates 27 and 27' are mounted on the upper and lower surfaces of the rear end portions of the piezo-electric vibrators 23 and of the dummy vibrators of the piezo-electric vibrators 23 and of the dummy vibrators

along cutting lines B or B' (double line) which divide the plates 24 into the front and rear end plates 26 and 27; and, in the lateral direction, it is cut along cutting lines A or A' (double line) which divide the plates 29 into the two equal parts, to obtain a plurality of piezo-electric plates 22. The piezo-electric plates 22 are sintered. Alternatively, first the aforementioned product may be sintered, and then cut in the above-described manner, to obtain a plurality of piezo-electric plates 22. Thereafter, as was described before, the front end portion of each of the piezo-electric plates 22 is cut into pieces like the teeth of a comb thus forming a number of piezo-electric vibrators 23.

As shown in Fig. 12, the piezo-electric vibrator assemblies thus manufactured are inserted into mounting holes 52 in such a manner that they face each other. In each of the assemblies, the metal plate 10 is protruded from the upper and lower ends and right and left ends of the rear end plates 27 and 27'. The metal plates 10 are bonded to the surfaces of mounting holes 52 with an adhesive agent 54. In this operation, each of the metal plates 10 is positioned by using guide grooves formed on both sides of the mounting hole 52, so that the piezo-electric vibrators are set on the island portions 49 of the vibrating board 47 with high accuracy and the piezo-electric vibrators 3 are prevented from being inclined in the direction of thickness. That is, positioning the metal plate 10 in the above-described manner allows the piezo-electric vibrators 3 to be bonded to the rear surfaces of the island portions 49 of the vibrating board 47 with adhesive agents 59. The adhesive agents 59 are applied to the end faces of the piezo-electric vibrators 3 with the end faces piezo-electric vibrators in plane contact with the island portions 49.

manner that they are electrically connected to the conductive layer 67 formed on the upper surface of the piezo-electric vibrating board 64. On the upper surface of the rear end plate 65, an insulating region 76 having a predetermined width is provided adjacent to the conductive layer 75. Furthermore, the conductive layer 78 is provided adjacent to the insulating region 76 on the upper surface of the rear end plate 65, and the conductive layer 77 is provided on the rear end face of the product in such a manner that it is electrically connected to the other electrodes (drive electrodes in the embodiment), namely, the conductive layers 61 appearing in the rear end face of the piezo-electric vibrating board 64.

As shown in Fig. 14, the piezo-electric vibrating board 64 thus formed is fixedly mounted on a substrate 10, and then its front end portion is cut into pieces like the teeth of a comb as described above. Thereafter, a cable 82 having a conductive strip 80 and conductive strips 81 in the front end is soldered to the piezo-electric vibrating board 64 thus processed, so that the conductive strip 80 is connected to the common electrode, namely, the conductive layer 75, and the conductive strips 81 are connected to the conductive layer 78 divided at a predetermined interval.

In the embodiment as shown in Fig. 14, the front end plates 69 and 70 equal in structure to each other are mounted on the upper and lower surfaces of the front end portion of each of the piezo-electric vibrators 23. Similarly the rear end plates 65 and 66 equal in structure to each other are mounted on the upper and lower surfaces of the rear end portion of the piezo-electric vibrators 23. The front end palates and rear end plates prevent the piezo-electric vibrators from being bent in manufacturing because of the symmetric structure. The external conductive layers 67 also prevent the piezo-electric

The front end plates 69 and 70 are fixedly mounted on the upper and lower surface of the front end portion of the piezo-electric vibrating board 64, respectively. Similarly, the rear end plates 65 and 66 are fixedly mounted on the upper and lower surface of the rear end portion of the board 64, respectively. When necessary, the outer end portions of the front end plates and those of the rear end plates are cut along lines C-C and C'-C', respectively, as shown in Fig. 15(b).

The front end plates 69 and 70, and the rear end plates 65 and 66 may be formed by using a green sheet which is equal in composition to the piezo-electric vibrating board 64, or a green sheet of free-cutting ceramic. Alternatively, those green sheets may be stacked one on another to a desired thickness. The resultant product is sintered (see Fig. 15(b)).

Thereafter, the conductive layer 73 is formed on the front end faces of the piezo-electric vibrating board 64 and the conductive layers 74 and 75 are formed on the upper end side surface of the rear end plates 65 and 66, and the conductive layers 78 and 77 are formed on a part of the upper surface of the rear end plate 65 and rear end face respectively. The conductive layer 78 is utilized as connecting terminals to external devices.

The product thus formed is fixedly mounted on the substrate 10, for instance, with an adhesive, and then the front end portion thereof is cut at predetermined intervals into pieces like the teeth of a comb.

short circuiting the conductive layers 94 and 96 buried respectively in the rear end plates 87 and 88, the conductive layers 94 and 96 are shifted a predetermined distance g inwardly from the outer end faces of the latter 87 and 88, respectively. The same effect can be obtained by making cuts in the conductive layers 94 and 96.

These cuts may be made so that there is a break in the electrically conductive path from the outermost portions of the conductive layers 94 and 96 (which may be in electrical contact with the external conductive layers 75 and 77) to the inner portions of the conductive layers 94 and 96.

In the embodiment described above, the conductive layers are buried in the green sheets of ceramic. Hence, the resultant product, when sintered, is substantially equal in the degree of contraction to the piezo-electric vibrating board, which effectively prevents the piezo-electric vibrating board from warpage. When necessary, the outer end portions of the piezo-electric vibrator assembley may be cut as shown in Fig. 16(b).

Thereafter, as shown in Fig. 16(c), a first conductive layer 73 is formed on the front end faces of the piezo-electric vibrating board 64 and on the front end plates 85 and 86, a second conductive layer 78 is formed on the rear end faces of the rear end plates 87 and 88, and a third conductive layer 75 and 78 is formed on a part of the upper surface of the rear end plate 87.

Under this condition, similarly as in the above-described embodiment, the resultant product is fixedly mounted on the substrate 10, and then cut at predetermined intervals into pieces like the teeth of a comb as described above for the embodiment shown in Fig. 14.

Fig. 17 is a sectional view showing the structure of an ink jet recording head equipped with piezo-electric vibrator assemblies which have been formed in the above-described manner. The conductive layer 73 formed on the front end faces of the front end plates 85 and 86 and of the piezo-electric vibrating board 64 is in contact with the

CLAIMS

1. A piezo-electric driver for an ink jet recording head comprising:

a piezo-electric plate having a rear end face and at least a front end portion as an inactive region, and another portion in which conductive layers are laminated as an active region, said piezo-electric plate is cut at predetermined intervals to form a plurality of piezo-electric vibrators each having a front end face and a rear end face; and

a first pressure facilitating front end plate mounted on at least a first surface of said inactive region of said piezo-electric plate such that a front end face of said first front end plate is flush with said front end face of said piezo-electric vibrators.

2. A piezo-electric driver as claimed in claim 1 further comprising a second pressure facilitating front end plate mounted on a second surface of said inactive region opposite said first surface, such that a front end face of said second front end plate is flush with said front end face of said piezo-electric vibrators.

3. A piezo-electric driver as claimed in claim 1 or 2 wherein a rear end face opposite said front end face of said first and said second pressure facilitating front end plates is sloped backwardly.

4. A piezo-electric driver as claimed in claim 1, 2 or 3 wherein said piezo-electric plate has an inactive rear end portion, said piezo-electric driver further comprising a piezo-electric element coupling rear end plate mounted on at least a first side of said rear end portion, said rear end plate having a rear end face and an upper surface.

5. A piezo-electric driver as claimed in claim 4 further comprising side plates mounted on both sides of said piezo-electric plate in such a manner that said side plates merge with said front end plate and said rear end plate.

a conductive layer on said front end faces of said piezo-electric vibrators and said front end face of said front end plate, said conductive layer being electrically connected to said external conductive layer.

12. A piezo-electric driver as claimed in any one of claims 4, 5 or 6 further comprising:

an external conductive layer on an upper surface of said piezo-electric vibrators;

a conductive layer on said front end face of said front end plate and said front end face of said piezo-electric vibrators electrically connected to said external conductive layer;

a conductive layer on said rear end face of said piezo-electric plat and on said rear end face of said rear end plate; and

a conductive layer formed on part of said upper surface of said rear end plate.

13. A method of manufacturing a piezo-electric driver for an ink jet recording head comprising the steps of:

laminating a piezo-electric material and a conductive material to form a piezo-electric plate having a front end face and having at least a front end portion of which is an inactive region;

mounting a pressure facilitating front end plate having a front end face on at least a first surface of said inactive region in such a manner that said front end face of said front end plate is flush with said front end face of said piezo-electric plate; and

cutting said piezo-electric plate together with said front end plate at predetermined intervals to form a plurality of piezo-electric elements.

14. A method as claimed in claim 13 wherein said laminating step further includes the step of forming a piezo-electric plate with an inactive front end portion and an inactive rear end portion and further comprising the steps of mounting a piezo-electric element coupling rear end plate on said inactive rear portion.

laying lateral plate forming materials onto said plate forming laminate in the lateral direction of said plate forming laminate;

cutting said laminate longitudinally along lines which divide said front end plates and said rear end plates of said plate forming materials; and

cutting said laminate laterally along lines which substantially divide said lateral plates onto two parts, to form a plurality of piezo-electric plates.

21. A method as claimed in claim 13 or 14 wherein the front end portion of said piezo-electric plate is cut at predetermined intervals until the cutting line reaches the straight line connecting the rear edge of said front end plate on said piezo-electric plate and the front edge of said rear and inactive region, to form a plurality of piezo-electric elements.

22. A method as claimed in claim 13 or 14 further comprising the steps of:

forming on the upper surface of said piezo-electric plate an external conductive layer which is extended to said front end of said piezo-electric plate; and

forming a conductive film on said front end faces of said piezo-electric plate and on said front end plate which electrically connects said conductive material to said external conductive layer.

23. A method as claimed in claim 13, 14 or 22 wherein said front end plate is formed by laminating a plurality of green sheets of ceramic to a predetermined thickness and sintering said green sheets thus laminated.

24. A method as claimed in claim 24 wherein said conductive layers are buried in said front end plate.

25. A method as claimed in anyone of claims 13 to 24 in which

on the upper and lower surfaces of inactive regions of a piezo-electric plate of forming laminate which is formed by using a piezo-electric material and a conductive material;

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Examiner's report to the Comptroller under Section 17
(The Search report)

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Documents considered relevant following a search in respect of Claims :-
1 TO 19 AND 21 TO 28

Relevant Technical Fields

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(ii) Int Cl (Ed.6) B41J 2/025, 2/045; H01L 41/04, 41/09

Databases (see below)
(i) UK Patent Office collections of GB, EP, WO and US patent specifications.

(ii)

Categories of documents

X: Document indicating lack of novelty or of inventive step.

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A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages	Relevant to claim(s)
X	EP 0550030 A2 (SEIKO)	26 to 28
X	US 4566018 (SIEMENS)	26 to 28
X	US 4438441 (SIEMENS)	26 to 28
X	US 4409601 (SIEMENS)	26 to 28

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